Multilevel Approach in the Optimization of Technological Processes in ATM

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Abstract

Air Traffic Management (ATM) is a complex system in which it is necessary to establish good subsystem coordination in order to realize a coherent and efficient service. In the process from the system design to putting into operation, a cooperation of a large number of experts on joint coordination and exchange of know-how and information is needed. A large portion of time is lost on explanation and presentation of ideas as well as exchange of ideas between persons of different professional profiles.

Due to ATM system complexity, a change in one segment can have a large impact on the overall technological processes so that the cooperation among all the people involved with the design of ATM technological processes is required.

Based on the results achieved through the detailed analysis of the technological processes by applying UML tools, this paper gives options for the decrease of duration time for specific operations as well as the exchange of specific actions by employment of advanced information and communication systems, i.e. intelligent systems.

The aim of the suggested solutions is to improve the ATM system performances in regard to the increase of throughput and safety of air traffic using the multilevel approach.

Key words. *traffic management, multilevel model, process optimization, UML*

1 Introduction

Modern traffic control systems, which enable the provision of holistic ATM (Air Traffic Management) services through the integration of different subsystems, grow increasingly complex.

In the process from the system design to putting into operation, a cooperation of a large number of experts on joint coordination and exchange of know-how and information is needed. A large portion of time is lost on explanation and presentation of ideas as well as the exchange of ideas between persons of different professional profiles, since the ATM system is very complex and a change on one segment can have a large influence on the overall air traffic management system. The cooperation among all the people involved with the design of ATM technological processes is required at all times. Through the UML tools application, which would be used from the project start up and further from the exploitation phases to personnel education, the optimization of individual ATM processes is possible.

This paper entails an example of ATM process analysis and the illustration of possible optimization manner of the same process by the UML (Unified/Universal Modeling Language) tools application.

The process and the interdependence of the phases of technological processes are observed on the example of a flight between two airports. Through the multilevel process analysis, an insight in all process phases for different expert groups is enabled. In this way it is possible to observe weak spots. Through the solving of those weak spots a shorter coordination time would be achieved.

2 ATM services

The functioning of the whole ATM system demands the cooperation of the neighboring air traffic controls, airports, airlines as well as the connection of information and communication systems of all the participants. Some of primary ATM services are organized through different services such as [1]:

- ATS Air Traffic Service
- FIS Flight Information Service
- SAR Search and Rescue
- ATS System capacity
- Air Traffic Flow Management

Airplane flights from one airport to the other can bee observed by means of the multilevel model. On every level complex coordination processes and information exchange with other levels or other users are executed.

Process and coordination interconnectedness in all phases is very important for air traffic safety as well as for the optimum use of air corridor traffic capacities, airports and airline resources.

Making of technological processes is sometimes very complex considering the fact that various services and experts from different areas and knowledge levels participate in the ATM processes.

Picture 1 shows the flight process of an airplane between two cities on the higher level, i.e. the basic airplane flight phases made in accordance with the focus of this paper are shown. In the process, a line of subjects is involved with automatic or oral information exchange. For each preparation, processing and realization segment of that flight, it is necessary to conduct a large number of operations in different ATM organization units and work positions whether it involves air traffic control, airports, airlines, etc. [4].

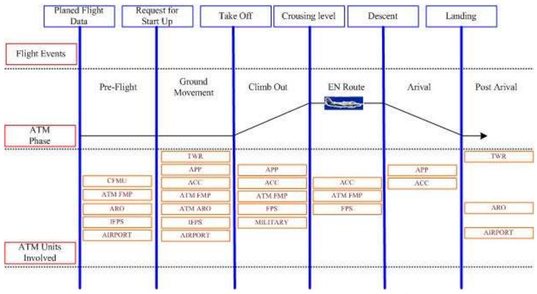

Figure 1. Phases and process during an airplane flight

3 Integration of ATM services

Predictions about air traffic increase also demand the application of a new and modern ATM system concept, which would be based on modern information and communication technologies in order to satisfy the demand for traffic increase. The existing ATM systems are not sufficiently integrated. They are comprised of multiple individual segments. Specialized personnel operate on those segments without having a complete overview of the effect of their work environment on the complete ATM service [3].

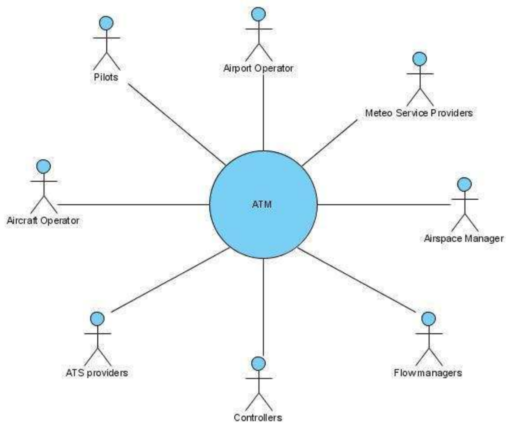

Figure 2. ATM users

The aeronautical community encompasses a large scope of service users, service providers, telecommunication equipment manufacturers, airports, airlines, army, government organizations, etc.

Each of them has his specific needs and expectations (Figure 2) and participates with his work in the provision of ATM service, whereas the knowledge of the whole process or the process of other users is nowadays either insignificant or nonexistent.

The impact of an individual activity on the overall ATM process can be quite extensive. The issue here is how to present every segment to all the participants of different profiles and expertise levels in ATM in the best way possible and thus improve the overall system using the experience of all ATM participants.

The second important issue within ATM is system incompatibility and the impossibility of automatic message exchange. Currently most of the message exchange between the participants is done by voice communication, which significantly slows down the functioning of the entire system and increases the personnel workload, which eventually causes lower traffic safety and traffic capacities. Often the ATM system operating technology is solved on local levels by observing only one's own segment. Such solutions can give rise to the workload transfer from one segment to the other, by which finally the optimization of the whole system is not achieved but rather the load is transferred on some other segment or participant in ATM processes.

Possible solution to this problem is to realize the overview of the functions of the entire system as well as the presentation of operations and services of all users through UML. It would enable system improvement, optimization and better understanding of the functionality of the whole ATM process by all the participants [2].

4 Processes in ATM

Figure 3 shows a simplified *Sequence diagram* of an airplane flight phases from one to the other airport. In the flight process, several in-flight services and operations are involved as well as message types exchanged before and during the flight.

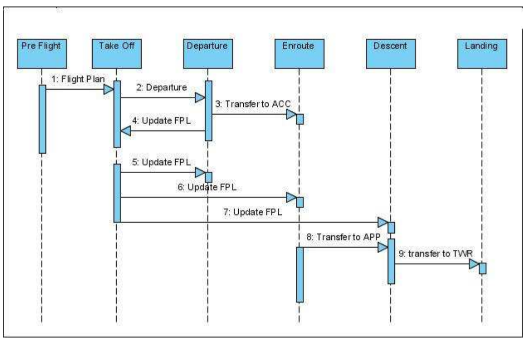

Figure 3. Airplane flight phases

The flight plan is updated according to the take off time and forwarded as an active flight plan to everyone. Each in-flight process includes a series of sub processes on lower levels. Some of them will be analyzed in detail in this paper and presented by means of UML with the aim of coordination optimization in ATM.

In order to present the demand for the realization of a solution or a project as precise and clear as possible, it is necessary to find a solution for the communication of air traffic controllers, programmers, telecommunication service providers, airports, airlines, etc. There is a problem of communication in ATM between users, designers, programmers, etc. who all speak different languages. In fact, each group of people that participates in a certain life cycle development phase of the ATM system or some of its services uses their individual way of description of organization, processes, data, statics and dynamics of the future system.

The introduction of UML would significantly simplify the process design, system programming, ensuring higher quality services and the functioning of the whole system.

5 Examples of possible UML application in ATM

Through the stated examples, possible use of UML for presenting the operating technology of certain services and the analysis of some of the technological processes within ATM is shown.

5.1 Pre Flight phase

An airplane flight begins with the making of flight plan filled out by a pilot in ARO (Air Traffic Services Reporting Office). After the flight plan is entered, it is sent via AFTN (Aeronautical Fixed Telecommunication Network) network to the master computer IFPS (Initial Flight Plan System), which receives all the flight plans and distributes them further to all the participants in air traffic as well as to CFMU (Central Flow Management Unit) for analysis and slot and route allocation i.e. flight plan clearance. Figure 4 shows the processes in the *Case Diagram* for the period of the flight plan preparation or the *Pre Flight* phase.

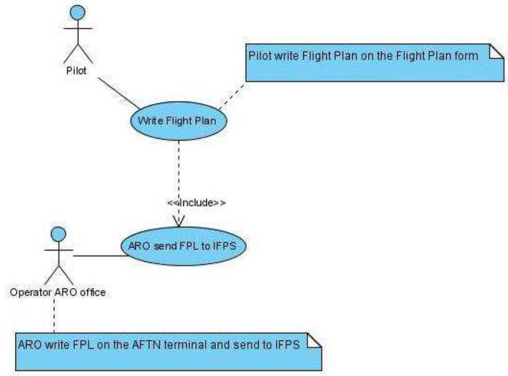

Figure 4. *Pre Flight* phase

Before the flight, the pilot gathers the information in the ARO office on all the relevant data necessary for the flight and on everything that could possibly affect his flight (Figure 5).

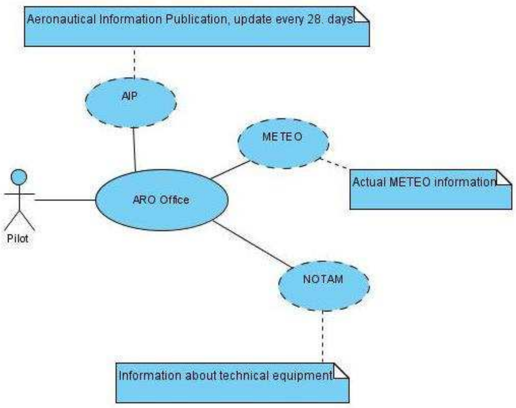

Figure 5. Pilot's gathering of information in the ARO office

Apart from the simple graphic illustration using the *Use Case* diagram, it is possible to conduct each action precisely and to define in detail the timeline realization frame by the use of adjusted program tools.

5.2 Ground Movement phase

The application of the *Sequence Diagram* enables a detailed illustration of every flight phase. The given example includes the *Ground Movement* phase (Figure 6), which is conducted by the air traffic controller assistant. His task is to prepare the airplane for the *Take Off* phase. The *Ground Movement* controller is responsible for the movement of an airplane on the maneuvering surfaces and parking positions. In this phase the coordination of airport services in the airport is necessary, the processes of which can also be shown by a *Sequence Diagram*.

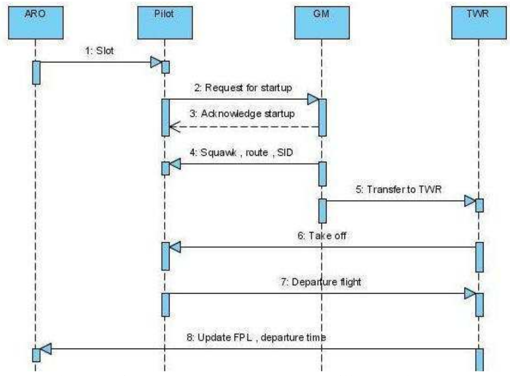

Figure 6. *Ground Movement* flight phase

After the plane take off, the flight plan is updated and sent to IFPS and to all the interested participants. At the take off, the flight plan becomes active and sent to work positions TWR, APP, ACC as well as to other En Route participants depending on the landing airport.

5.3 *Take Off* flight phase

In the *Take Off* flight phase, the TWR (Tower) controller brings the airplane outside the airport area (Figure 7).

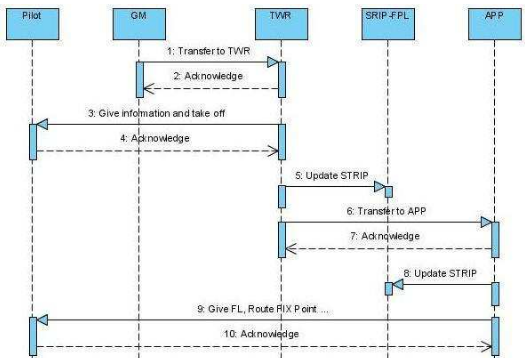

Figure 7. Take off flight phase

The Ground Movement and Take off controllers enlist all the operations and activities in the STRIP and update every change (Figure 8). STRIP is prepared before the flight by an assistant controller separately for arrivals, departures and transfers.

The data from STRIP are also enlisted via AFTN network in the computer and sent to IFPS in order to update CFMU with current information for the Tactical Flight Planning and further airplane flight phases.

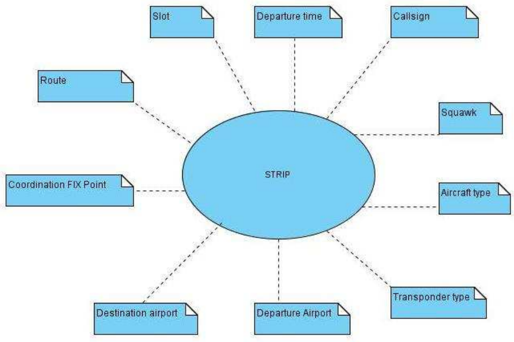

Figure 8. Data recording on STRIP

6 Analysis of activities and coordination in the *Take Off* flight phase

With the aim to achieve optimization of the oral communication system and predict the necessary capacities of communication systems, a detailed analysis of coordination among different positions was conducted.

The analysis is also conducted in order to see the possibility of exchange of certain coordination processes in which oral communication with other systems for message exchange is currently used.

Sometimes the coordination is conducted in time critical frameworks in which the communication availability must be almost 100%. Every failure in communication can lead to the degradation of ATM services.

In order to optimize the process, a detailed analysis of every integral part of the system was conducted through the airplane flight phases by the use of UML, i.e. activities of individual work positions were shown. The analysis enables a simpler recognition of critical points in the coordination between work positions with the recording of the duration time of each activity.

6.1 Analysis of the ARO work position activities

As opposed to the air traffic control services, the ARO service does not use the oral A/G (Air Ground) communication with the aircraft since the oral communication is lowered at the minimum through the use of information systems. In this case, the voice G/G (Ground / Ground) communication is used as a backup in case of an error in any of the systems.

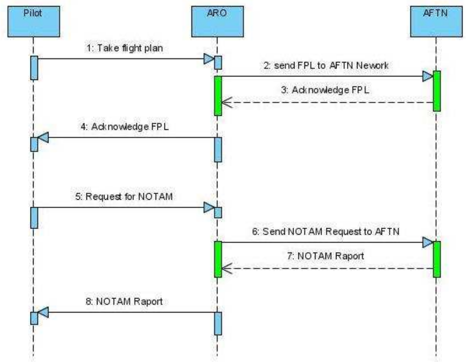

Figure 9. Activities of the ARO work position

In the shown diagram (Figure 9), it is observable that the ARO office communicates with the pilots giving them the required flight information such as NOTAM (Notice to Airmen) information, meteorological maps, etc.

6.2 Analysis of the TWR work position activities

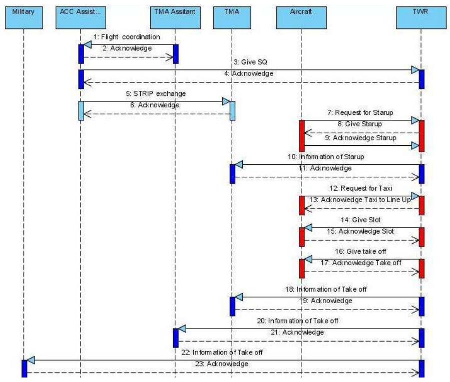

Figure 10. Activities of the TWR work positions

Figure 10 illustrates the technological process in the *Take Off* flight phase in the work positions TWR and APP (Approach Control). The process involves data communication systems, systems for A/G radio communications and G/G for oral communication. It is noticeable that the process begins by physical activities such as STRIP printing, which demands the operator to work on the STRIP writing. After the STRIP printing, the operator conducts G/G oral communication for the allocation of the aircraft identification Squawk code. This type of coordination demands the use of communication G/G resources.

The STRIP must also be located at the APP controller work position. After the take off, a large part of the communication is done via A/G radio communication systems for interservice communication. Each of the communications is executed through the defined procedure.

The analysis done by the application of *Sequence Diagram* shows that a large part of work activities is conducted without the significant application of the information systems, which would significantly relieve oral communication systems and operator workload. Activities such as STRIP printing, and similar can be optimized through the application of information systems.

In the shown UML diagram, the communication with outer ATM service users such as airports and army is also visible. The exchange of messages is done orally. Considering the fact that the messages are the same, that part can also be automated and this would additionally unburden the work position of TWR controller.

6.3 Analysis of the TMA work position activities

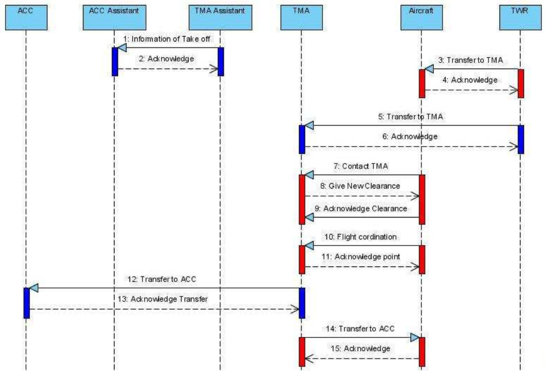

Figure 11. Activities of the TMA work position

From the activities analysis through the *Sequence Diagram* (Figure 11), it is observable that the coordination between the ACC (Area Control Centre) and TMA (Terminal Area) is executed orally, by application of computer systems and message exchange. This segment of the technological process can be additionally improved and thus work positions of TMA controller and assistant controller disencumbered. Voice A/G communication represents at the moment a critical part of the technological process pertaining to time and it is necessary to relieve every work position as much as possible in which this communication is executed because it has the highest priority in the performance of operation.

6.4 Analysis of the TMA assistant work position activities

As opposed to the previous phase in this phase (Figure 12), oral communication is used largely for the information exchange on the flight and the information on the aircraft handover points. Operations such as STRIP printing and updating can also be optimized through the application of information systems.

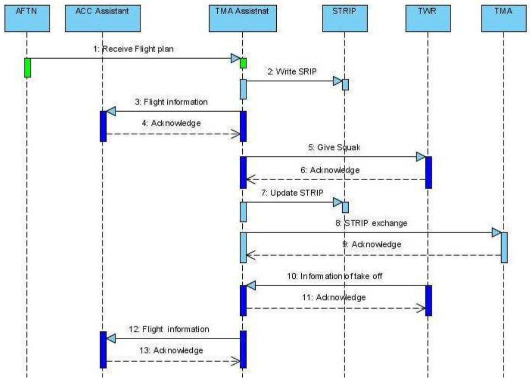

Figure 12. Activities of the TMA assistant work position

Most of the time critical coordination operations are executed by applying the A/G and G/G communication systems. Depending on the flight phase, the coordination must be executed in a strictly limited time so as not to degrade the ATM services. The availability of the oral communication system through which the coordination is done must amount to almost 100% and the delay in speech transmission must be lowered at the minimum values recommended by ICAO and EUROCONTROL.

7 Optimization of technological processes

The stated examples show that the mechanical operations such as STRIP printing and updating are present in all work positions (TMA, TWR i ARO) and take up a large part of time of the operating personnel.

Execution of those operations additionally burdens the work positions in charge of time sensitive operations in the A/G communications such as TWR, APP, TMA i ACC.

The STRIP preparation done in work positions of assistant controller and TWR can be completely automated by application of various technical solutions whether it is the electronic STRIP or automatic STRIP printing.

The purpose of UML in the stated examples is the analysis of technological processes and process design through the application of information systems. Diagrams showing all the participants in detail as well as their work activities can considerably help designers and programmers of the necessary information systems and also technologists for the adaptation of the work technology and finally for education in order to get the aircraft personnel acquainted in detail with the new work technology.

Apart from the STRIP printing operation, the optimization of information exchange about the airplane take off and landing can be considered. It is possible to exchange those messages by the application of information systems.

Since those messages are exchanged with outer ATM participants, who do not know the air traffic control services operations, the UML diagram represents a good solution for the communication among technologists, programmers, engineers, etc., with the aim to realize the optimization of technological processes and technological systems.

8. Conclusion

Today it is impossible to envision the new ATM systems without the application of information systems. The need for the introduction of new technologies and higher air traffic safety also demands the upgrading of the current air traffic technology.

It is very difficult to unite all the system segments and to know every part in details. From the presented examples of processes, phases and activities in ATM, it is visible that the application of UML tools significantly simplifies their understanding, i.e. the interconnections and interdependence of technological process in ATM.

The greatest problem in the application of UML tools is the education and preparation of users for working with and reading of such documents. In case that the UML is applied from the very beginning of system design as a tool for setting the demands on the system, system design, project management, personnel education, software design, it would considerably facilitate the introduction of new systems and technological processes as well as their monitoring and maintenance.

The need for the inclusion of an increasing number of users in the ATM system demands informing the personnel about the system operation and their role, which is significantly facilitated by the application of UML tools in order to accept the standard communication manner among all the participants.

The conducted analysis of the technological processes point to the possible lowering of the coordination time and increase in safety, which eventually leads to the increase in the throughput of air traffic corridors and airports.

9 References

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